NOTE ON THE OCCURRENCE OF DIATOMACEOUS EARTH AT THE WARRUMBUNGLE MOUNTAINS, NEW SOUTH WALES.

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(Plates xv.-xvii.)

I.—*Introduction.*

Deposits of diatomaceous earth have been recorded as occurring in New South Wales at the following localities:—Barraba (between Tamworth and Bingara); the Lismore District; the Richmond River; the Tweed River; Cooma; Newbridge; and the Warrumbungle Mountains. The deposit near Barraba has been described by Mr. E. F. Pittman, the Government Geologist, in general terms.*

Mr. Pittman states that the diatomaceous earth is capped by basalt, and attains a thickness of about 8 feet, having a layer of coarse sand (2 inches thick) about 3 feet from the top. The infusorial earth rests on a bed of sandy mudstone, about 1 foot in thickness, under which is an impure infusorial deposit containing rolled pebbles and fragments of imbedded lava, pointing to the fact that volcanic eruptions were common at the time of its deposition. Finally, an overwhelming flow of lava filled up what was, doubtless, during the Miocene epoch, a lake, and it now forms an elevated tableland. As far as I am aware, this is the only reference to the mode of occurrence of diatomaceous earth in New South Wales. Descriptions have been given by other observers of hand specimens of the diatomaceous earth.

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* Ann. Rept. Dep. Mines, 1881, pp. 142-143. By Authority. Sydney, 1882.

In 1888 Professor Liversidge published an account of *Tripoli or Infusorial Earth*,* from Barraba.

He states that the "tripoli" at Barraba is made up almost entirely of the remains of Diatoms resembling *Melosira*. The same author refers to a deposit (*op. cit.* p. 194) of "cimolite" from the Richmond River. There can now be little doubt that this material, described as "a very white and porous hydrous silicate of alumina,† often sent down to Sydney as meerschaum," must graduate into a clayey diatomaceous earth, as Diatoms in some numbers have been observed by me in a similar rock from the same locality. Professor Liversidge gives analyses of the rocks from both the above localities.

Mr. R. Etheridge, Junr., has published a short description of some hand specimens of the diatomaceous earth from the Warrumbungle Mountains, and also of similar specimens respectively from the Lismore District, Tweed River, and Richmond River Districts.‡

He refers the barrel-shaped Diatoms, so conspicuous in these deposits, to *Melosira*, and notes the association with them of spicules of freshwater sponges.

Last September Judge Docker and the author were afforded an opportunity, through the kindness of Mr. W. L. R. Gipps, of Bearbong Station, of examining the deposit of diatomaceous earth in the Warrumbungle Mountains.

II.—*General Geological Features of the District.*

In the neighbourhood of the diatomaceous earth deposit there are two formations represented:—(1) The Permo-Carboniferous Coal-measures, and (2) Trachyte lavas, dykes, and tuffs,

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* The Minerals of New South Wales, &c. By A. Liversidge, M.A., F.R.S. p. 177. Trübner & Co. London, 1888.

† Ann. Rept. Dep. Mines, for the year 1887, pp. 165-166. By Authority. Sydney, 1888.

‡ Ann. Rept. Dep. Mines, for the year 1888, p. 190. By Authority. Sydney, 1889.

with which last are associated the deposits of diatomaceous earth, and a seam of lignite. It is not my intention here to attempt to give a detailed description of that grand chain of trachytic volcanoes, of which the Warrumbungle Mountains form a not insignificant portion. Suffice it to say that they are the wrecks of large volcanoes; and their cores of coarsely crystalline trachyte, which have cooled deep down in the volcanic chimneys, now rear themselves skywards as gigantic monoliths, between 3,000 and 4,000 feet above the sea, and over 2,000 feet above the surrounding plain, ringed round with alternating beds of coarse trachyte tuff and lava.

The chain extended probably from at least as far south as the Canobolas, near Orange, northwards, perhaps, with intervals, to the Glass-House Mountains on the coast north of Brisbane, a distance of nearly 400 miles. As the diatomaceous earth deposits are interstratified with the trachytes it is obvious that any evidence which throws light upon the age of the trachytes has an equally important bearing upon the question as to the age of the diatomaceous earths.

As shown on Plate xv., accompanying this paper, there is clear evidence to show that the trachytes have intruded the Permo-Carboniferous Coal-measures in this neighbourhood. The latter consist of sandstones, quartzites, cherts containing well preserved specimens of *Glossopteris*, finely laminated black shales, and at least one seam of coal, over 6 feet in thickness. The coal has been calcined by the trachyte dykes, and at the extreme right of the section, beds of trachyte tuff are seen resting, with strong uncomformity, on the Permo-Carboniferous strata. Obviously then the eruption of the trachytes was later than Permo-Carboniferous time.

At several localities in the Warrumbungle Mountains the trachyte series is seen to overlie sandstones, which are almost certainly of Triassic age, and in this case the trachytes would be proved to be Triassic or Post-Triassic.

If now the chain of trachytic volcanoes be followed up into Queensland, and traced north of the Glass-House Mountains, it may be noted that near Port Mackay trachyte lavas and tuffs are

abundantly interstratified with rocks of the Desert Sandstone Series, the age of which is Upper Cretaceous.*

It is unlikely that these extensive eruptions took place in Lower Cretaceous time, as that was a period of prolonged subsidence, and Mr. R. L. Jack has commented on the fact that in Queensland, at any rate, no lavas nor tuffs have as yet been noted in the Rolling Downs Series (Lower Cretaceous). As regards the downward limit in time of these eruptions, it is improbable, therefore, that it was earlier than Upper Cretaceous.

As regards the upward limit, the following considerations suggest themselves:—It is improbable that the Warrumbungle trachyte volcanoes, at the time they were active, were far distant from the sea. They are now over 300 miles inland from the Pacific, but during the Lower Cretaceous epoch the waters of the inland sea, which, at that time, must have extended from the Gulf of Carpentaria to the Australian Bight, must very nearly have washed the bases of the Warrumbungles. In Upper Cretaceous time elevation took place, and marine conditions were largely replaced in Central Australia by shallow lacustrine conditions. There is no evidence to show that marine conditions obtained within a hundred miles of the Warrumbungles in Tertiary time. On physical evidence therefore it might be inferred that the age of the trachyte series might be placed at the close of the Cretaceous, or at the commencement of the Eocene periods. There is also some palæontological evidence in support of this supposition, as will be stated in the next division of this paper.

III.—*Details of the Diatomaceous Earth Deposit.*

The deposit makes two distinct outcrops at the bottom of the shallow valley or gully through which flows Wantialable Creek.

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* "Geological Features and Mineral Resources of the Mackay District." By A. G. Maitland. By Authority. Brisbane, 1889. *Also see* Geology and Palæontology of Queensland and New Guinea. Jack & Etheridge, Junr. Text. pp. 546-547. 1892.

As shown in the upper section on Plate XVI. a sheet of trachyte at least 20 feet thick caps the ridge overlooking Wantialable Creek. Below this is a thickness of about 30 feet of trachyte tuff varying in texture from fine to coarse. A remarkable rock succeeds which I have termed a silicified trachyte tuff, 1½ ft. to 2 ft. thick. This rock has already been ably described by Mr. G. W. Card,* the Mineralogist to the Geological Survey of the Department of Mines.

Underlying this is another also very remarkable bed of trachyte tuff, almost exclusively composed of translucent crystals of sanidine, from a fraction of an inch up to ½ an inch in diameter. The crystals exhibit their usual tabular habit, the clinopinacoid faces being extensively developed. The bed being only loosely coherent, the rain washes quantities of the larger sanidines out of it, and forms with them miniature snow-white talus slopes.

Next follows the bed of diatomaceous earth, 3 feet 9 inches thick; then come 19 feet 3 inches of strata, chiefly trachyte tuffs, resting on the surface of a sheet of vesicular trachyte. Half-a-mile higher up the creek, the lower section shown on Plate XVI. may be studied. It resembles the section above quoted, but in addition fossil leaves occur on a horizon immediately above and intimately associated with the diatomaceous earth, as was shown me by Mr. W. L. R. Gipps. We had here the good fortune to discover a fossil leaf fairly well preserved in the fine tuff, which Mr. R. Etheridge, jun., and Mr. W. S. Dun, Assistant Palæontologist to the Geological Survey, identify as *Cinnamomum Leichhardtii*, Ettingshausen. (See Plate accompanying this paper). This leaf is elsewhere in Australia associated with Eocene deposits.

The age therefore of the Diatoms and of the freshwater sponge spicules associated with them at this spot may, I think, be provisionally set down as early Eocene or late Cretaceous.

I have purposely abstained from attempting a detailed description of the different species of Diatoms and sponges represented

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* Records Geol. Surv. N.S. Wales. Vol. iv. Pt. iii. pp. 115-117. Plate x. By authority. Sydney. 1895.

in this deposit, as I understand that this is a work which has already been commenced by Mr. W. S. Dun and Mr. G. W. Card, and an interesting paper from them on this subject may shortly be expected. I would merely add that *Melosira* appears to greatly predominate among the Diatoms, but not to the entire exclusion of other forms. The sponge spicules are acerate or fusiform, slightly arcuate, and some are thorny, but the majority smooth.

I should like to emphasise the fact that hitherto all our diatomaceous earths in New South Wales have been found in association with volcanic rocks, and I would venture to suggest that this association is probably far from accidental. The superheated water flowing from hot springs and from the lavas themselves during the trachytic eruptions would be certain to carry more or less silica in solution, and its high temperature, combined with its dissolved silica, would probably render it a very favourable medium for the development of Diatoms to the exclusion of most other kinds of plant. While some species of Diatoms flourish luxuriantly in the cold waters of the Antarctic Ocean, others may be found equally flourishing in the hot and highly mineralised waters of geysers. For example, Mr. H. N. Moseley* has described the occurrence of Diatoms near the Boiling Springs at Furnas, St. Michael's, Azores, and their neighbourhood.

Mr. Moseley states (*op. cit.* p. 322) "The *Chroococcus* [*Botryococcus Braunii*, Ktz., as would appear from the footnote. T. W. E. D.] was not so abundant in the samples of incrusting matter in this hot spring as in those from the spring at Furnas. Amongst the green matter are a few skeletons of *Diatomaceæ* (a *Navicula*); but these are very probably derived from a cool spring, situate just above the sulphur spring, the water of which mingles with that of the sulphur spring, and indeed appears to supply a large share of the water of most of the hot springs, the water being merely heated and impregnated with various

* Journ. Linn. Soc. Bot. Vol. xiv. p. 322.

minerals by the discharge of steam and various gases from apertures in the several basins into which it finds its way. . . . The small cool spring above referred to contains abundance of *Navicule* and other Diatoms, such as those met with amongst the green matter growing in very hot water." He also observes (*op. cit.* p. 323), "In this water, which was too hot to bear the finger, the same *Chroococcus* as observed at the springs near the lake was abundant," etc. . . . "A little lower down in a small pool of hot mud and water, so hot that the finger could only be borne in it for a short time, grows a sedge . . . and an abundant growth of algæ, *Chroococcus*, *Oscillatoriæ* [*Tolyphothrix* f. Archer. T.W.E.D] and some Diatoms with endochrome complete."

The temperature of the springs in the lake of Furnas is quoted (*op. cit.* p. 324), f. Hartung* as from 78° to 190° Fahr. The water in which the *Chroococcus* grew is estimated to have had a temperature of 149° to 158° Fahr., and that in which the sedges grew of 113° to 122° Fahr. Mr. W. T. Thiselton Dyer, in notes on Mr. Moseley's collections (*op. cit.* p. 326), states that in the collection submitted to him "from among the sedges at Furnas in very hot water" he identified a number of Diatoms, which he specifically names. He adds that they were not numerously represented, however, and says (p. 327), "These are all forms of common occurrence, and seemed in no way affected by the high temperature of the water." A useful bibliography of references to the vegetation of hot waters is contained in Ninth Report, Geol. Sur. U.S.A. 1887-88, pp. 620-628. It is noted (*op. cit.* p. 625, quoted from Manual of Geology, by James D. Dana, 3rd ed., 1880, p. 611) that "Mr. James Blake found diatoms in water having a temperature of 163° F. at Pueblo Hot Springs, Nevada." It is also stated (*ibidem*), "At the Mammoth Hot Springs, Dr. F. V. Hayden observed the occurrence of pale yellow filaments about the springs and the green confervoid vegetation of the waters, as well as the presence of diatoms in the basins of the main springs, two species of the latter, *Palmella* and *Oscillaria*,

* "Die Azoren," Leipzig, W. Englemann, 1860, p. 173.

being recognized by D. Billings." . . . (*Op. cit.* p. 627) "The extreme temperature at which vegetation has been observed is 200° F., recorded by Prof. W. H. Brewer at the California Geysers."

It is clear therefore that Diatoms are capable of flourishing in the waters of hot springs, the water of which must necessarily be more or less highly mineralised, though apparently they do not flourish in water at so high a temperature as that in which some algæ, such as the *Oscillatoriæ*, can flourish. The fact must not be forgotten that spicules of *Spongilla* are at the Warrumbungle Mountains associated with the Diatoms, and obviously if the Diatoms flourished in hot water the Sponges must have existed under similar conditions.

Animal life was well represented in the neighbourhood of Furnas by Rhizopods, but no mention is made of freshwater sponges.

It is at all events certain that at the Warrumbungle Mountains the Diatom *Melosira* and a variety of *Spongilla* occur in association with trachytic lavas and tuffs of early Tertiary, possibly of late Cretaceous Age.

EXPLANATION OF PLATES.

Plate XV.

Section showing junction between the Trachyte Volcanic Group of the Warrumbungle Mountains, and the Permo-Carboniferous Coal Measures in a tributary of Uargon Creek, Wollongulgong, near Tooraweena, N.S.W.

Plate XVI.

Upper Figure.

Section in Wantialable Creek, near Tooraweena, Warrumbungle Mountains, showing intercalation of Diatomaceous Earth in the Trachyte Series.

Lower Figure.

Section in Wantialable Creek, near Tooraweena, Warrumbungle Mountains, showing Diatomaceous Earth in association with *Cinnamomum Leichhardtii.*

Plate XVII.

Cinnamomum Leichhardtii, Ettings.